AD-A281 784

USAARL Report No. 94-28

# Switching from Forward-Looking Infrared to Night Vision Goggles: Transitory Effects on Visual Resolution

(Reprint)



By

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and

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June 1994



United States Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

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Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

# REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

| | |
|---|---|
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| 2a. SECURITY CLASSIFICATION AUTHORITY | 3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited |
| 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE | |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S): USAARL Report No. 94-28 | 5. MONITORING ORGANIZATION REPORT NUMBER(S) |
| 6a. NAME OF PERFORMING ORGANIZATION: U.S. Army Aeromedical Research Laboratory; 6b. OFFICE SYMBOL (If applicable): SGRD-UAS-VS | 7a. NAME OF MONITORING ORGANIZATION: U.S. Army Medical Research, Development, Acquisition and Logistics Command(Provisional) |
| 6c. ADDRESS (City, State, and ZIP Code): P.O. Box 620577, Ft. Rucker, AL 36362-0577 | 7b. ADDRESS (City, State, and ZIP Code): Fort Detrick, Frederick, MD 21702-5012 |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION; 8b. OFFICE SYMBOL (If applicable) | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER |
| 8c. ADDRESS (City, State, and ZIP Code) | 10. SOURCE OF FUNDING NUMBERS |

| PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO. |
|---|---|---|---|
| 0602787A | 3M162787A879 | PE | 164 |

11. TITLE (Include Security Classification)
(U) Switching from Forward-Looking Infrared to Night Vision Goggles: Transitory Effects on Visual Resolution

12. PERSONAL AUTHOR(S)
Jeff Rabin and Roger Wiley

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14. DATE OF REPORT (Year, Month, Day) | 15. PAGE COUNT |
|---|---|---|---|
| Final | FROM ____ TO ____ | 1994 June | 3 |

16. SUPPLEMENTARY NOTATION
Printed in Aviation, Space, and Environmental Medicine, April 1994, pages 327-329

17. COSATI CODES

| FIELD | GROUP | SUB-GROUP |
|---|---|---|
| 17 | 05 | |
| 20 | 06 | |

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Night vision devices, forward-looking infrared, luminance adaptation, visual resolution

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Helmet-mounted displays under development for rotary- and fixed-wing aircraft will allow the user to switch electronically between forward looking infrared (FLIR) and night vision goggle (NVG) sensors. These sensor transitions potentially involve large changes in display luminance which could transiently impair visual resolution and performance. The purpose of this study was to identify the display luminances which produce a transient reduction in vision when switching from a higher luminance (FLIR) to a lower luminance (NVG) display. A letter recognition task was used to assess the effect of luminance adaptation on visual resolution in five subjects. A significant reduction in letter recognition was observed in the first second after switching from simulated FLIR to simulated NVGs when the FLIR luminance was ≥10 fL. By varying letter size, contrast, and exposure time, the magnitude and duration of visual loss after switching from a bright (49.2 fL) FLIR display were determined. The visual loss lasted up to 4 sec, and included a 2x reduction in visual acuity, and a 3x reduction in contrast sensitivity. Large differences in sensor display luminance should be avoided to maintain high levels of visual performance and aviation safety. Design features or training may be necessary to achieve a proper balance between FLIR and NVG luminances which optimize performance and safety without sacrificing the quality of the sensor image.


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|---|---|
| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS | 21. ABSTRACT SECURITY CLASSIFICATION: Unclassified |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL: Chief, Scientific Support Center | 22b. TELEPHONE (Include Area Code): (205) 255-6907; 22c. OFFICE SYMBOL: SGRD-UAX-SI |

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

# Switching from Forward-Looking Infrared to Night Vision Goggles: Transitory Effects on Visual Resolution

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RABIN J, WILEY R. *Switching from forward-looking infrared to night vision goggles: transitory effects on visual resolution.* Aviat. Space Environ. Med. 1994; 65:327–9.

**Helmet-mounted displays under development for rotary- and fixed-wing aircraft will allow the user to switch electronically between forward-looking infrared (FLIR) and night vision goggle (NVG) sensors. These sensor transitions potentially involve large changes in display luminance which could transiently impair visual resolution and performance. The purpose of this study was to identify the display luminances which produce a transient reduction in vision when switching from a higher luminance (i.e., FLIR) to a lower luminance (i.e., NVG) display. A letter recognition task was used to assess the effect of luminance adaptation on visual resolution in five subjects. A significant reduction in letter recognition was observed in the first second after switching from simulated FLIR to simulated NVG's when the FLIR luminance was ≥10 fL. By varying letter size, contrast, and exposure time, the magnitude and duration of visual loss after switching from a bright (49.2 fL) FLIR display were determined. The visual loss lasted up to 4 s, and included a 2× reduction in visual acuity, and a 3× reduction in contrast sensitivity. Large differences in sensor display luminance should be avoided to maintain high levels of visual performance and aviation safety. Design features or training may be necessary to achieve a proper balance between FLIR and NVG luminances which optimize performance and safety without sacrificing the quality of the sensor image.**

HELMET-MOUNTED displays being developed for rotary- and fixed-wing aircraft will allow the user to electronically switch between forward-looking infrared (FLIR) and night vision goggle (NVG) sensors. Since these sensors respond to different portions of the infrared spectrum, the capacity for rapid switching will allow performance over a greater range of environmental conditions. While NVG and FLIR displays will be similar in color and size, they may differ in several respects including perspective, contrast and luminance. Notwithstanding the benefit of switching between sensors, the user will be required to adapt to these different display characteristics.

The luminance of the NVG display is typically in the mesopic to low photopic range (0.3–2.0 fL), and cannot be adjusted by the user. It remains relatively constant in any one night sky condition. In comparison, the luminance of the FLIR display can be adjusted by the user to be nearly 100× brighter than NVG's (5,11,12). Rapid transitions from a bright FLIR display to a much dimmer NVG display may impose adaptational demands on the visual system that lead to a transient decrement in visual performance (1,2,10).

The purpose of this study was to determine the display luminances that produce a transient reduction in vision after switching from a brighter (FLIR) to a dimmer (NVG) display. Since luminance adaptation involves photochemical and neural events that change over time, vision is also in a state of transition, making measurement of visual performance difficult (1–3,9,10). Thus, in the present study, vision was assessed in discrete intervals following adaptation to simulated FLIR displays. Observers adapted to luminances comparable to FLIR, and then attempted to recognize letters presented at the luminance of an NVG display. By varying letter size, contrast, and exposure time, it was possible to estimate the extent and duration of visual loss after switching from a very bright to a dim display. Recommendations are made regarding the proper balance between FLIR and NVG display luminances.

## METHODS

A letter recognition task was used to evaluate the effect of switching from a bright (simulated FLIR) to a dim (simulated NVG) display. Stimuli were computer-generated and displayed on a color monitor in an otherwise dark room. Luminance was measured with a calibrated photometer and stored in tabular form. Only the

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This manuscript was received for review in March 1993. It was revised in June and July 1993 and accepted for publication in July 1993.

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green phosphor of the monitor was used to simulate the green displays of NVG's and FLIR. The simulated FLIR display was uniform, green, and subtended an angle of 5° at a viewing distance of 2.7 m. A small, low contrast cross centered in this display was used to guide fixation. This display, which served as the adaptation field, was replaced periodically by a lower luminance test display (simulated NVG display) consisting of a single letter centered in the screen. The letter was always darker than its background, and the background was held constant at 0.6 fL, representing the luminance of an NVG display in moderate (¼ moon to starlight) night sky conditions. Monocular viewing was used to prevent fluctuations in binocular posture from possibly influencing the results.

The procedure consisted of having the subject adapt to the simulated FLIR display for 20 s, followed by a 1 s test interval in which the subject attempted to recognize a single letter centered in the screen at the luminance of NVG's. The adaptation field then reappeared and the adaptation-test cycle was repeated on subsequent trials during which different parameters (adaptation luminance, letter size, contrast, and duration) were varied. In the first session, the luminance of the FLIR display was varied from trial to trial to determine those values which produced an adverse effect on letter recognition with NVG's. The adaptation luminances ranged from 0.6 to 49.2 fL in approximately 3× steps. Two letter sizes, chosen to be near recognition threshold, were used to assess high contrast (20/21 letter; 99.5% contrast) and low contrast (20/42 letter; 27.1%) letter recognition. Contrast was expressed as Weber values (background-letter/background × 100). Luminances were presented in ascending order to reduce successive adaptation effects.

In separate sessions, letter size, contrast, and exposure duration were varied to determine the magnitude and duration of visual loss following luminance adaptation. The luminance of each 20 s adaptation display was maintained at the highest level (49.2 fL) while the test field was again 0.6 fL. In one session, letter size (20/21, 20/42, 20/84; 99.5% contrast) and letter contrast (27.1%, 51.0%, and 99.5%; 20/42 letter) were varied from trial to trial. In a separate session, the duration of letter exposure (0.5, 1, 2 or 4 s) was varied between trials. Each trial was repeated 4 times for each condition (size, contrast, and duration), and the percent correct was determined for each subject.

Five adult volunteers (age 22 to 31; mean = 26.4 years) with normal ocular health and visual acuity corrected with spectacles to 20/20 participated in this study. Following protocol approval by our institutional review board, informed consent was obtained after each subject was briefed on all procedures. Subjects were told they could withdraw at any time.

## RESULTS

Fig. 1 shows the relation between letter recognition on a simulated NVG display after switching from a FLIR display of equal or higher luminance. Mean percent correct (five subjects) is plotted against the luminance of the adaptation field. Because results with high

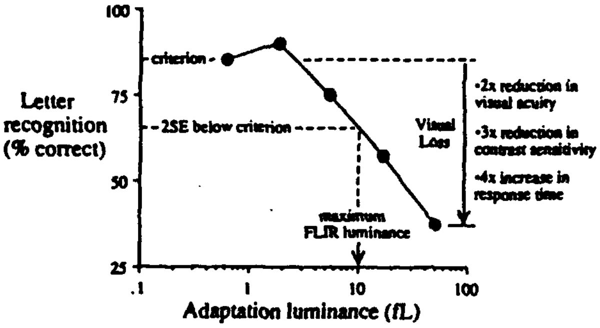


**Fig. 1. The mean percent correct letter recognition from five subjects is plotted against the luminance of the adaptation field. The letters were high (99.5%) and low (27.1%) contrast presented at a luminance comparable to an NVG display (0.6 fL), while the adaptation luminances included a range of values possible with FLIR. The mean percent correct obtained when test and adaptation fields were of equal luminance is denoted criterion, and the value 2SE below the criterion was used to determine the maximum recommended FLIR luminance. The average amount of transient visual loss which occurred after switching from the highest luminance display (49.2 fL) is indicated on the right as reductions in visual acuity and contrast sensitivity, and as an increase in response time.**

and low contrast letters were not significantly different ($F_{1,40}$ = 2.62; $p > 0.10$), values were averaged across these two conditions. The response obtained with adaptation and test fields of equal luminance (85% correct) is denoted criterion. Fig. 1 shows that as the luminance of the adaptation field was increased, the percentage of correct responses increased slightly and then decreased, falling 2 SE below the criterion when the adaptation luminance was 10 fL. This indicates that a transient yet significant reduction in visual resolution of NVG targets can occur after switching from a FLIR display which is ≥10 fL.

While Fig. 1 demonstrates the FLIR luminance which is likely to produce transient visual loss after switching to NVG's, the magnitude and duration of this effect are not evident in these results. What is the visual consequence of maintaining the FLIR intensity at a high level if one is to switch from FLIR to NVG's? To explore this issue, letter size, contrast, and exposure duration were varied from trial to trial with adaptation maintained at the highest level (49.2 fL). Thus, we determined the increase in letter size, contrast, and exposure duration necessary to overcome a large luminance adaptation effect. Results are summarized on the right side of Fig. 1 as changes in visual acuity, contrast sensitivity, and response time. Following adaptation to the 49.2 fL field, letter size had to be increased an average of 2× (20/21 to 20/42), letter contrast 3× (27.1% to 81.3%), and exposure duration 4× (from 1 to 4 s) to overcome the adaptation effect and achieve criterion performance. In terms of both magnitude and duration, these transient visual decrements are nontrivial and stress the importance of maintaining a proper balance between FLIR and NVG display luminances.

## DISCUSSION

The purpose of this study was to determine the display luminances which produce an adverse effect on visual resolution after switching from a higher luminance (FLIR) to a lower luminance (NVG) display. A significant reduction in letter recognition was observed in the first 1 s after switching from simulated FLIR to simulated NVG when the FLIR luminance was $\geq$10 fL. By varying letter size, contrast, and exposure duration, it was possible to estimate the magnitude and duration of visual loss after switching from a very bright (49.2 fL) FLIR display. This visual loss, which lasted up to 4 s, included a 2× reduction in visual acuity, and a 3× reduction in contrast sensitivity.

A transitory reduction in resolution after switching from FLIR to NVG's could interfere with object recognition during critical periods of aircraft control, target acquisition, and firing. It is recommended that large differences in luminance be avoided to optimize visual performance and safety. A FLIR display luminance no greater than 10 fL should minimize any visual loss after switching to NVG's. Because current and planned FLIR systems have no specific user indications of display luminance, it may be necessary to incorporate a perceptual technique in which the pilot matches the brightness of the two displays to ensure that the luminance difference is within the recommended range. A neutral density filter of fixed amount before the FLIR display could be used to match brightness within the desired range. Alternatively, an intensity indicator could be included in the design. The choice of display luminances also may be governed by other factors, such as the quality of FLIR imagery obtained at different luminances, and under varying environmental conditions.

Since the present study was conducted with *simulations* of FLIR and NVG displays, caution should be exercised in applying the results directly to aviation performance. The simulations subtended a considerably smaller area than the actual displays, and lacked the dynamic imagery experienced in flight. However, these factors should not influence local adaptation effects responsible for the visual loss observed in this study (1,9). It is of interest that luminance adaptation produced a slightly greater reduction in contrast sensitivity than visual acuity for letters of similar size (20/20–20/40). This result, however, may be expected from the shape of the contrast sensitivity function which, for higher spatial frequencies, changes more rapidly for contrast than size (6,7). A clinical application of the present result may be to use small letter contrast sensitivity, rather than acuity, to reveal abnormal luminance adaptation in the clinical photostress recovery test (4,8).

ACKNOWLEDGMENTS

Grateful acknowledgment is extended to James Wicks and James Bohling for their assistance.

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